Shallow Scattering Layer (SSL): Emergence Behaviors of Coastal Macrofauna

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LONG-TERM GOALS

Our long-term goals are to understand — to an extent that allows quantitative prediction — important interactions among acoustic propagation, marine organisms, particles (including sediments), solutes and moving fluids. The reason for these goals is to allow us to solve interesting forward and inverse problems in the marine environment.

OBJECTIVES

The objectives of this work are to develop a predictive understanding of emergence by coastal macrofauna in one region. By emergence we mean leaving the seabed to become part of the plankton or nekton, which typically occurs at night. In high-frequency acoustic records, this emergence appears as a "shallow scattering layer" that typically leaves the seabed after dusk and returns before dawn. Emergence and re-entry in shallow water appear to represent an evolutionary solution that avoids visual predation analogously with oceanic "deep scattering layers." In the coastal zone, the water is simply too shallow to provide a holoplanktonic solution.

The region selected for this work is midcoast Maine in the vicinity of the Darling Marine Center, which is located, mid-estuary on the lower Damariscotta River. The region was chosen for its diversity of estuarine and coastal environments, including a range of optical properties in river and coastal waters. We caution that it may be more representative of coastal waters than of an estuary because of the small freshwater input.

APPROACH

The first field season focused on two-point measures of spatial coherence in emergence with two TAPS-6 (Tracor Acoustic Profiling System with six frequencies). We suspect that in addition to the obvious vertical component, shallow-water emergence also has an onshore-offshore component. The second phase will entail production of explicit models of emergence behaviors, building on the work of De Robertis (2002) and using local monitoring of phytoplankton abundance by M.J. Perry. The third phase will export the model to a new location and will use TAPS-6 measurements to test its predictions.

Complementing this evolution of the scientific questions, we are enhancing remote access to TAPS-6 for diagnostics, programming and data collection. The first phase of this enhancement will be wireless

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implementation of an emulation program for the PCs that control data acquisition and programming for TAPS-6. The wireless component will connect the pier to the Darling Center intranet and thereby to the internet. This approach will allow us and personnel at BAE SYSTEMS to monitor system performance much more efficiently for troubleshooting. This phase will be implemented in late fall 2003 after the major effort to get simultaneous records from two TAPS-6 instruments during the season of emergence (May-October) has passed. The next phase will be implementation of a Matlab-based data acquisition program. This implementatin will streamline the Matlab-based analysis and further enhance data archiving and web access.

WORK COMPLETED

We are early in the first year of the work but already late in the field season. Emergence in our location terminates in late October. We are behind schedule because we have been unable to keep both TAPS-6 units operating continuously. Our two-point measurements are limited to 20 d of observations with the TAPS-6 instruments moored 50 m apart in the alongshore direction. With the help of Charles Greenlaw and Van Holliday of BAE SYSTEMS, we have narrowed the causes for erratic behavior of both instruments to power supply. By replacing both the power-control cards and batteries in both units we hope to get at least one multi-week record with the TAPS-6 instruments separated in the cross-stream (onshore-offshore) direction before the end of October.

We continue to take advantage of unpaired TAPS-6 data collected in summer 2003 and in prior years under previous funding (N00014-00-1-0662) to develop predictive capabilities. We have completed extensive analyses and two draft manuscripts extracted from two M.S. theses.

RESULTS

Visual inspection of our earliest emergence results, application of a simple algorithm (Kringel *et al.* 2003) and the published literature led us to focus on the emergence and re-entry events close to dusk and dawn, respectively. The Damariscotta data, however, are sufficiently noisy that we did extensive algorithm development. A simple threshold scheme detects near-dawn and near-dusk events (Abello 2003), but a more complex algorithm combining backscatter intensity and duration of elevated backscatter levels proved necessary to consistently locate and further characterize high-density, long-lasting emergence events (Taylor 2003).

The dusk emergence event apparently is cued by relative rate of change in irradiance. Emergence timing coincided with a relative rate of change in irradiance (dimensionless) of -0.0023. Very interestingly, although this small a negative rate of change occurs only fairly near dark, this cue apparently caused emergence under a range of absolute irradiances. When irradiances were higher at the time of emergence, emergers compensated by ascending more slowly (Abello 2003; Abello *et al.,* in preparation). Overall, group ascent and descent speeds were slower than those found in a deeper water column in Puget Sound by Kringel *et al. (*2003) despite the order-of-magnitude greater tidal velocities in the Damariscotta River.

The larger, longer-lasting event occurs on the first tidal deceleration after dark, but emergence traps reveal that both events are dominated by *Neomysis americana* (Taylor 2003 and Taylor *et al.,* in preparation). Onset of this emergence event is predicted better from tidal height predictions than from either local tidal height (smoothed or not) or local tidal velocity (smoothed, vertically integrated or not)

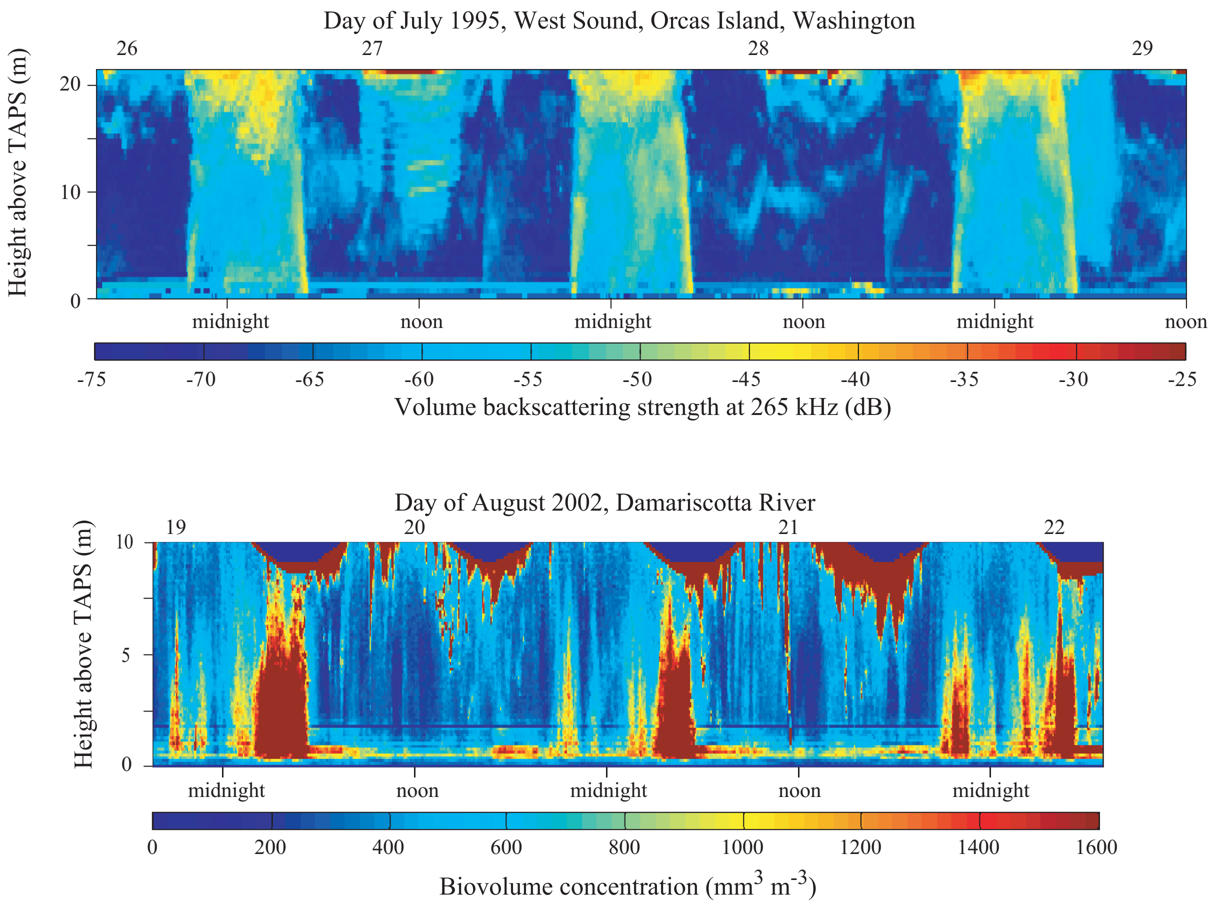

Figure 1. A visual comparison of three consecutive nights of emergence patterns in West Sound, Orcas Island, Washington (top panel, from Kringel et al. 2003) and the Damariscotta River (lower panel). Both localities show a near-dusk emergence and other emergence events later in the night, but the regularity of the near-dusk emergence and near-dawn return in the West Sound record is more striking. Note that the panels have been aligned so that midnight and noon correspond, but the tides are almost perfectly out of phase in the two records (with low tides visible as red regions that represent high backscatter from the air-sea interface (near noon for the low lows of the upper figure and with the two more symmetric lows bracketing noon in the lower figure).

from ADCP measurements. For this reason we suspect that the behavior is circatidal, but we will further test this idea against TAPS-6 results separated in the onshore-offshore direction. Do individuals at deeper sites emerge at the same time as individuals at shallow sites? If so, do they reach surface waters at similar times? Our first results with TAPS-6 instruments separated by 50 m show high coherence, but they were collected at the same water depth.

Our initial data record for West Sound, Orcas Island, Washington (Kringel *et al.* 2003), is too short to correlate effectively with tidal stage, but also suggests a large event after dark (Fig. 1). We do have longer records near the Friday Harbor Laboratories that we will analyze for tidal effects *after* we finalize a predictive model for the Damariscotta River.

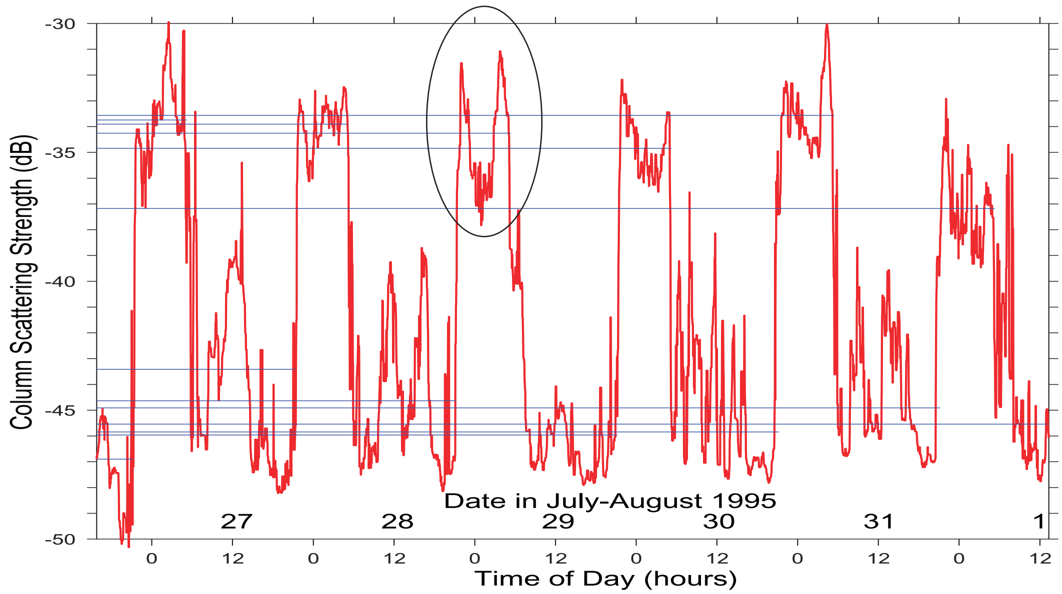

Figure 2. Column scattering strength at 265 kHz versus time for the six nights of data recorded in West Sound, Orcas Island, Washington. Nighttime levels were seven times larger than daytime levels. Note also (oval "circled" region) the "molar" structure that we most often see in column scattering strength. This drop in the middle of the night does not appear to correspond to any coherent re-entry into the seabed and is one clue that there may be an offshore-onshore component in the migration.

IMPACT/APPLICATIONS

Because emergent fauna can dominate volume reverberation of near-bottom waters (Fig. 2), they can strongly influence the performance of high-frequency acoustics that may be used in mine detection and classification. Models that accurately predict timing of emergence should aid materially in improving performance by allowing operators to avoid times when volume reverberation is high.

RELATED PROJECTS

Sara Lindsay (University of Maine, Orono) and I continue to model the microtopographic impacts of fish feeding (N00014-02-1-0091, now expired). We may combine our modeling and SAX99-related field estimates with Chris Jones' (Applied Physics Laboratory, University of Washington) measurements of goldfish pock marking in a laboratory tank.

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PUBLICATIONS

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